Available online at www.sciencedirect.com
ScienceDirect
Renewable and Sustainable Energy Reviews 13 (2009) 473–478
RENEWABLE & SUSTAINABLE ENERGY REVIEWS
www.elsevier.com/locate/rser

Wind energy status in electrical energy production of Turkey

Önder Güler *

Istanbul Technical University, Energy Institute, Ayazaga Campus, 34469 Maslak, Istanbul, Turkey

Received 22 January 2007; accepted 21 March 2007

Abstract

Main electrical energy sources of Turkey are thermal (lignite, natural gas, coal, fuel oil, etc.) and hydraulic. Most of the thermal sources are derived from natural gas. Turkey imports natural gas; therefore, decreasing usage of natural gas is very important for both economical and environmental aspects. Because of disadvantages of fossil fuels, renewable energy sources are getting importance for sustainable energy development and environmental protection. Among the renewable sources, Turkey has very high wind energy potential. However the installed wind power capacity is only 0.22% of total economical wind potential. In this study, Turkey's installed electric power capacity, electric energy production is investigated and also Turkey current wind energy status is examined.

Keywords: Electrical energy; Wind energy; Installed wind power capacity

Contents

1. Introduction

There has been a significant increase in electrical energy demand due to the economical and technological developments over the world. The global economy grew 3.3% per year over the past 30 years. In this period the electrical energy demand increased 3.6% [1]. The electrical energy production of the world in 2004 was 17,450 TWh [2] and it is estimated that the world will consume 31,657 TWh in 2030 [3]. In order to supply the required electricity demand, thousands of new power plants had to be built.

Electrical energy production has been mainly derived from limited sources. Because of this fossil sources will be consumed in the future, studies on electrical energy production with renewable sources such as hydraulic, solar, wind, biomass and geothermal continue on with the energy saving studies at the same time. It is now widely accepted that renewable energy sources are very important for the future of the countries.

The ratio of the electric power produced via usage of renewable resources except hydroelectricity in 2002 is only 2% and it will be intented to increase this proportion up to 6% until 2030 [3]. It is expected that biomass and wind energy will have a great effect in this increase. The objective is to increase the wind energy up to 929 TWh with a rate of 3% of the world electricity production in 2030 [1], which has a 1% proportion in 2005 [4]. So the greatest increase will be in wind energy production. This rate reached 20% in Denmark, 6% in Germany for the year 2003 [5].

Wind energy is domestic, independent to abroad, natural and infinite, obtained in the future as same amount, does not cause

* Tel.: +90 212 285 38 70; fax: +90 212 285 38 84.
E-mail address: onder.guler@itu.edu.tr.

1364-0321/$ – see front matter
doi:10.1016/j.rser.2007.03.015

acid rain or atmospheric heating, no CO_2 emission, no harm to nature and human health, providing fossil fuel saving, no radioactive effect, fast technological development and currency gaining sources [6–8]. Turkey has very high wind potential and should benefit from this source, which has many advantages.

In this paper, Turkey's existing electrical energy status is investigated and according to the recent developments on wind energy in the world, Turkey's wind energy status is considered and things to be done on this issue are stated.

2. Turkey's electrical energy status

Turkey's total installed power capacity obtained from hydraulic, thermal (natural gas, coal, lignite, fuel-oil, LPG, etc.) and wind sources, is 38,820 MW at the end of the 2005. Distribution of the installed power capacity of Turkey according to the sources is given in Fig. 1 [9,10]. As it is seen from Fig. 1, the rate of thermal sources power plants is very high and approximately half of these are natural gas plants. According to the estimation of Energy and Natural Sources Ministry, installed power would be necessary 60 GW until 2010 and 105 GW in 2020 [11].

The total gross electrical energy production in 2005 was 161,983.3 GWh and changes in the production rate depended on the economical situations and technological developments. Average increasing rate was approximately 8.82% in this term [12,13]. Turkey' s electrical energy production from 1970 to 2005 are shown in Fig. 2. Although electrical energy production has increased gradually, there was a decrease in electrical energy production in 2001, because of industrial electrical energy demand decreased as a result of economical crisis throughout the country.

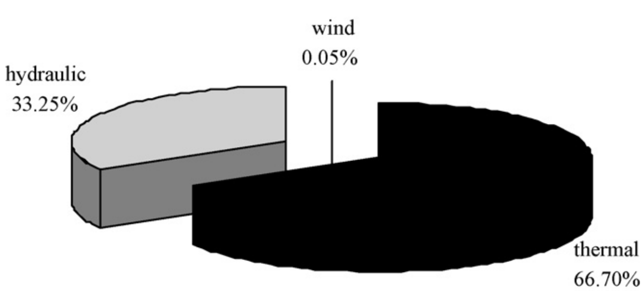


Fig. 1. Distribution of installed power capacity of Turkey.

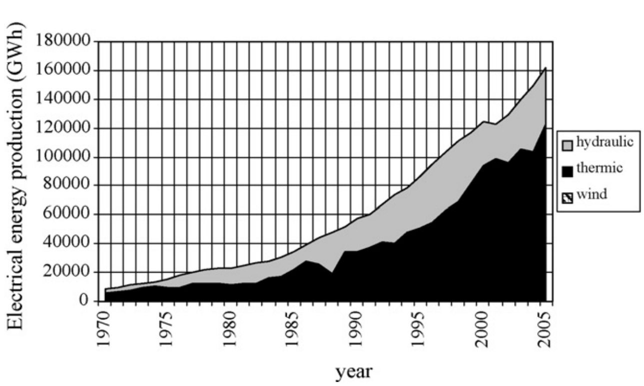


Fig. 2. Turkey's gross electrical energy production for the years 1970–2005.

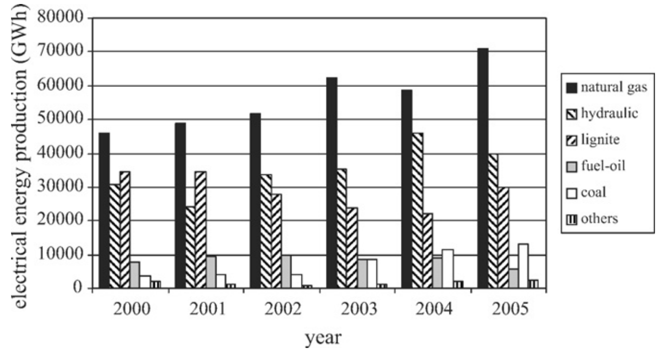


Fig. 3. Distribution of sources of the Turkey's gross electrical energy production.

Distribution of the gross electrical energy according to sources between 2000 and 2005 is shown in Fig. 3. As it is seen from Fig. 3, most of the electrical energy is supplied from thermal source [13]. It can be seen that the proportion of natural gas in the electrical energy production has increased in recent years. In electrical energy production, consumption of natural gas reaches to 43% in 2005 whereas it was 37% in 2000. However, the natural gas share of the world in production electrical energy is 19.6% [2]. Since Turkey imports almost all required natural gas, this high rate usage in producing electricity than the world is an important point to be examined economically [13]. On the other hand, the share of lignite in electricity generation decreases from 28% in 2000 to 19% in 2005 [13]. While electrical energy production from the wind has grown rapidly, in the World, especially in the Europe, usage of wind sources in Turkey is very low.

The average share of sources in electrical energy production between 2000 and 2005 are given in Table 1 [13].

3. Wind energy in the world

Total installed wind power capacity reached 58,982 MW at the end of 2005 in the world [4]. Fig. 4 shows installed wind power capacity in the world between 1996 and 2005 [4,5]. There is an increasing trend in installed wind energy and average increasing rate is 28% over this period. It is estimated that installed wind power will be reached in 120,000 MW in 2010 [4].

Approximately 69% of the installed wind capacity of the world is in the Europa, 17% in America and 12% in Asia. However, Germany has the highest installed wind capacity with 18,427.5 MW which is equal the 45% of European and 31.2%

Table 1
Average share of the sources in electrical energy production (2000–2005)

	Share (%)
Natural gas	40.8
Hydraulic	25.2
Lignite	21.3
Fuel-oil	6.3
Coal	5.3
Others	1.1

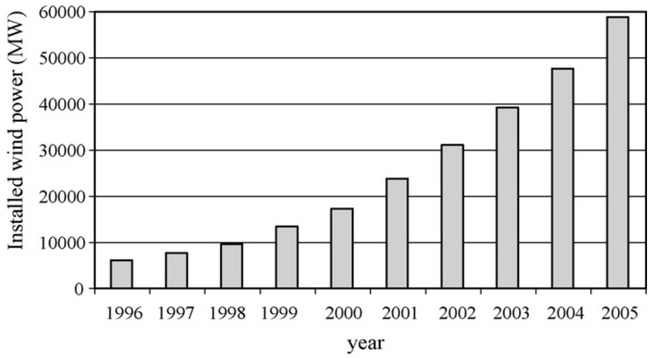


Fig. 4. Installed wind power capacity of the world.

Table 2
The top five wind energy markets point of view install wind capacity (MW)

Country	2000	2001	2002	2003	2004	2005
Germany	6,113	8,754	12,001	14,609	16628.8	18427.5
Spain	2,235	3,337	4,830	6,202	8263	10,027
United States	2,554	4,275	4,685	6,374	6740	9,149
India	1,167	1,407	1,702	2,110	2985	4,430
Denmark	2,300	2,417	2,880	3,110	3117	3,128

of world installed capacity. The top five wind energy markets are listed in Table 2 between 2000 and 2005 [4,5,14–16].

As it is seen from Table 2 Spain shows the highest development in installed wind energy capacity with 348.6% between 2000 and 2005. India, USA and Germany have also high development with 279.6, 258.2 and 201.4%, respectively. But increasing rate in Denmark is 36%. The average increasing rate of installed wind capacity in this term for Spain, India, USA, Germany is 35.4, 31.1, 30.9, 25.3%, respectively. The growing rate of Denmark in this term is 6.6%. According to the German Wind Energy Association, in a typical wind year, 6% of Germany's energy requirement can be supplied from the wind farms, and 45,000 people employed by wind energy industry in Germany. Spain, USA and Denmark supply 4–5, 1 and 20% of their electrical energy from wind, respectively. The highest wind energy rate in total electrical energy belongs to the Denmark [5].

Since wind power has significant development in electrical energy production in the Europen country and closer the Turkey as gheographically, it is important to determine the installed wind power capacity per km^2 (kW/km^2), and per capita (W/capita) of some European countries (Table 3). Also technical potential of wind energy, installed wind power capacity and the ratio installed wind power capacity to technical potential are given in Table 3 [17]. As it is seen from Table 3 the ratio of installed wind power to technical potential in Germany reached to 153.56%, the installed wind power capacity is 6427.5 MW higher than the technical potential. This rate in Austria, Netherlands, Spain and Denmark are 40.95, 40.63, 23.32 and 22.34%, respectively. Although Turkey has the highest technical wind energy potential, this rate as given in table is lowest. Germany has the highest installed wind capacity but Denmark has the highest install capacity both per km^2 and per capita [4,17].

4. Wind energy in Turkey

Turkey is located between 26° and 45° east latitudes to the Greenwich, and between 36° and 42° north longitudes to the Equator. Most of the land of Turkey is in Asia and the small part is in Europe. Turkey surrounded by sea on its three borders (Aegean Sea on the west, Black Sea on the north, Mediterranean on the south and Marmara as an inner sea). Aegean, Marmara and East Mediterranean coasts have high wind potential. According to the "Turkey Wind Map", prepared by General Directorate of Electrical Power Resources (EIE), wind speed at 50 m height and outside the residential areas, at Marmara, West Black sea, and East Mediterranean coasts and inner parts of these regions are 6.0–7.0, 4.5–5.0 m/s,

Table 3
Wind energy data for some European country

Country	Technical potential		Installed wind power (MW)	Installed wind power/technical potential (%)	kW/km^2	W/capita
	MW	TWh/year				
Austria	2,000	3	819	40.95	9.77	100.25
Belgium	2,000	5	167.4	8.37	5.14	16.29
Denmark	14,000	29	3,128	22.34	72.58	582.62
Finland	4,000	7	82	2.05	0.24	15.82
France	42,000	85	757.2	1.80	1.39	12.67
Germany	12,000	24	18427.5	153.56	51.61	221.35
Greece	22,000	44	573.3	2.61	4.34	53.85
Ireland	22,000	44	496	2.25	7.06	129.40
Italy	35,000	69	1717.4	4.91	5.70	22.63
Netherlands	3,000	7	1,219	40.63	29.36	75.87
Norway	38,000	76	270	0.71	0.83	59.67
Portugal	7,000	15	1,022	14.6	11.07	101.35
Spain	43,000	86	10,027	23.32	19.86	250.19
Swedeen	20,000	41	509.9	2.55	1.13	57.44
Switzerland	1,000	1	11.6	1.16	0.28	1.59
Turkey	83,000	166	21.84	0.03	0.03	0.31
U.K.	57,000	114	1,353	2.37	5.57	22.63

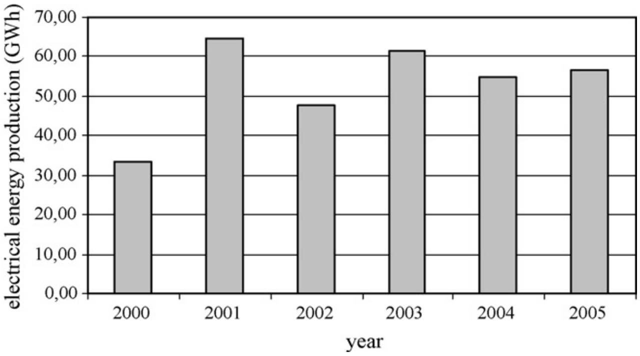


Fig. 5. Electrical energy production from wind.

respectively. The north-west Aegean coasts are also 7.0–8.5 m/s, and in the inner parts are 6.5–7.0 m/s [18]. In addition to this, meteorological data by the USA space studies have been shown that Turkey has high wind capacity [19].

It is estimated that Turkey's technical wind energy potential is 88,000 MW, economical potential is approximately 10,000 MW depending on the technical condition [20]. Wijk and Coelingh (1993) reported that, Turkey's technical wind energy potential was 83,000 MW, production potential was 166 TWh/year [17]. But, Turkey total installed wind capacity is only 21.84 MW [4,11].

The first wind power plant was installed in 1998 Çeşme-Germiyan with 1.74 MW capacity [19]. In 1998, the ARES wind farm was built in Çeşme-Alaçatı and includes 12× 600 kW wind turbines [19,21]. The biggest wind energy power plant in Turkey has 10.2 MW capacity constructed in Bozcaada in 2000 [21]. There are also some wind power plants established by private sector to supply their electrical energy needs. These are installed in Izmir in 2003 with 1.5 MW capacity and in Istanbul in 2003 with 1.2 MW capacity [10].

Changes in electrical energy production of Turkey from wind are shown in Fig. 5 [13]. Dramatically, it has only 0.035% of total electrical energy production of 2005.

In January 2005, 243 projects got licensed from Energy Market Regulatory Authority (EPDK) to produce electricity. Thirty-six of 243 projects are wind power plant projects. The planned capacity of these 36 wind power plants change between 0.66 and 135 MW and total capacity of all plants are 1406.92 MW. These wind projects were distributed in Marmara region (16 projects), Aegean region (10 projects), Mediterranean region (9 projects), and south-east Anatolia region (1 project), with 626.46, 343.01, 394.45, and 43 MW, respectively (Fig. 6). Geographical region, location, installed capacity, estimated gross electrical energy values and capacity factor of these projects are shown also in Table 4. It is estimated that totally 4763 GWh electrical energy will be produced which is equal to 2.94% of Turkey 2005 total electrical energy production [10].

Currently, 106 new wind power plant applications have been made to get generation license with 3309.63 MW capacity up to January 2005, from Energy Market Regulatory Authority. Distribution of these projects to the region are as follows: Marmara region (27 projects) with 847.3 MW, Aegean region (59 projects) with 1786.4 MW, Mediterranean region (17 projects) with 513.33 MW, middle Anatolia region (2 projects) with 115.2 MW, and south east Anatolia (1 project) with 47 MW [10].

5. Wind energy supports and prices

In all European country, production of electrical energy from renewable resources is supported. In many countries minimum price system is used widely. Electricity utility must purchase this energy, named as green energy, at a minimum price which is defined. Legally defined minimum prices changes according to the country, some of them are shown in Table 5 [22].

In Turkey to increase the usage of renewable energy sources renewable energy law has been accepted. The law, regarding the spread of the use of renewable energy resources (including the wind energy) with the aim of producing electrical energy, the economic and quality integration of these resources into the economy, the increase of the resource variety, the decrease of the emission of greenhouse gases, the reuse of waste, the preservation of the environment, and the development of the manufacturing sector needed for realizing these goals, was enacted on 18 May 2005, with the official number of 5346.



Fig. 6. Licensed wind power plants from EPDK after January 2005.

Table 4
Licensed wind power plants from EPDK after January 2005

Region	Location	Established power (MW)	Production (estimated) (kWh/year)	Capacity factor (%)
Marmara	Bilecik/Kapaklıköy	67	202,479,010	34.5
Marmara	Çanakkale/Karacaören	29.7	103,600,000	39.8
Marmara	Balıkesir/Bandırma	30	105,000,000	40.0
Marmara	Balıkesir/Şamlı	90	440,000,000	55.8
Marmara	İstanbul/Kumburgaz	0.66	1,920,000	33.2
Marmara	Kocaeli/Hereke	90.9	300,000,000	37.7
Marmara	Balıkesir/Bandırma	15	60,000,000	45.7
Marmara	İstanbul/Çatalca	62	210,000,000	38.7
Marmara	Bursa/Karacabey	26.1	68,600,000	30.0
Marmara	Bursa/Karacabey	42	130,691,708	35.5
Marmara	Çanakkale/İntepe	30	92,420,000	35.2
Marmara	İstanbul/Eyüp	24.3	76,700,000	36.0
Marmara	Kocaeli/Hereke	28.8	88,000,000	34.9
Marmara	Tekirdağ/Saray	45	118,914,000	30.2
Marmara	Çanakkale/Gelibolu	15	47,660,000	36.3
Marmara	Balıkesir/Ayvalık	30	106,456,000	40.5
Aegean	Manisa/Akhisar	43.75	123,049,000	32.1
Aegean	İzmir/Aliağa	41.25	160,896,500	44.5
Aegean	Manisa/Sayalar	30	97,170,000	37.0
Aegean	Aydın/Söke	21.25	52,020,000	27.9
Aegean	İzmir/Bergama	55.8	200,000,000	40.9
Aegean	Aydın/Çine	24.3	68,000,000	31.9
Aegean	Muğla/Fethiye	24.3	60,000,000	28.2
Aegean	İzmir/Kemalpaşa	66.66	235,035,050	40.2
Aegean	Manisa/Akhisar	10.5	30,100,000	32.7
Aegean	Denizli/Babadağ	25.2	68,500,000	31.0
Mediterranean	Hatay/Samandağ	30	100,000,000	38.1
Mediterranean	Hatay/Belen	19.8	66,500,000	38.3
Mediterranean	Hatay/Samandağ	50	181,576,000	41.5
Mediterranean	Hatay/Samandağ	22.5	102,000,000	51.8
Mediterranean	Hatay/Mağaracık	35.1	140,000,000	45.5
Mediterranean	Osmaniye/Kabaklar	27.9	77,930,556	31.9
Mediterranean	Osmaniye/Türkbahçe	27.9	115,000,000	47.1
Mediterranean	Osmaniye/Bahçe	135	403,000,000	34.1
Mediterranean	Karaman/Sertavulgeçidi	46.25	150,929,000	37.3
South-east Anatolia	Adıyaman/Kahta	43	123,628,748	32.8

The electrical energy produced from the renewable energy resources stated in this law was officially guaranteed to be purchased. The price that applies to the purchase in a given year until 2011 is the average wholesale price of the previous year determined by the EPDK. The board of ministries is entitled to increase this price by at most 20% [23]. The average electricity price of Turkey is 8.36 YKr/kWh (approximately is 4.6 Euro cent/kWh) for the year 2005. It is stated by the World Wind Energy Association (WWEA), the price determined as the purchase guarantee for wind energy in the renewable energy law should be raised to the level in the European Wind Markets [24].

Table 5
Minimum price of wind electricity in some European country

Country	Price (Euro cent/kWh)
Germany	6.2–8.5
France	8.4
Portugal	7.5–7.9
Austria	7.8
Spain	6.3–7.5
Greece	6.4
Netherlands	9.6–9.9

In addition to the purchase guarantee, in the case of the use of the public lands and forests for the production of electrical energy from the renewable resources, these lands can be rented or awarded access by the Ministry of Environment and Forestry and/or Finance. Fifty percent discount applies in the period of investment. In the forest fields, ORKOY and the private budget revenues are not collected [23].

6. Conclusions

Although estimated installed wind power capacity and average electrical energy production from the wind in eighth 5-year improvement plan for the year 2005 are 643 MW, 1926 GWh, respectively, the realisation values are 21.84 MW, 56.6 GWh [19]. The installed wind capacity of Turkey is only 0.22% of Turkey's total economical wind potential. However this rate will be increased to 14.27% after installing the licensed projects.

It is possible to improve the present wind energy capacity to the European countries' levels by increasing government supports, constituting necessary technological background to connect to the interconnected network. Turkey should invest to

the wind turbine technology both for using its wind potential more cheaply in a long period and for supplying job opportunity to the people. Turkey will become technologically independent and could export technology. Conclusively, the use of present wind potential is very important from both economical and environmental respects.

When considering the energy reserves in the world, it is obvious that wind power is very important. The depletion of the world energy reserve is 200 years for coal, 65 years for natural gas, 40 years for petroleum and infinite for wind [6]. Since the energy reserves are going to end in the future, for Turkey who imports most of its fossil energy sources will most probably be a great problem. Therefore, it is necessary to use existing hydraulic sources accompanying with wind energy which is renewable sources, to obtain electrical energy.

Research studies for decreasing carbon emission supported primary wind energy and also renewable energy sources. The use of hydraulic energy potential was being admired. Trend in the world through the renewable sources because of many advantages, therefore Turkey should increase expenditures on renewable energy.

References

[1] World Energy Outlook 2004, International Energy Agency; 2004.
[2] Key World Energy Statistic, International Energy Agency; 2006.
[3] Power Generation Investment in Electricity Production, International Energy Agency; 2003.
[4] Press Release; March 7, 2006. http://www.wwindea.org.
[5] American Wind Energy Association, Global wind energy market report, Wind energy industry grows at steady pace; March 2004. http://www.awea.org.
[6] Karadeli S. Wind Energy, Clean Energy Society. Ankara: Tubitak Press; 2001 [in Turkish].
[7] U.S. Department of the Interior 2004, Wind energy development programmatic environmental impact statement. http://windeis.anl.gov/documents.
[8] Energy Research, 2003. The European Commission Website on Energy Research. http://www.europa.ea.int.
[9] Ergün S. Productivity parameters in Turkey energy sector (electricity, gas, water). In: Proceedings of the 5th Energy Symposium; 2005. p. 399–419 [in Turkish].
[10] Energy Market Regulatory Authority (EPDK). http://www.epdk.gov.tr.
[11] Energy Policies of IEA Countries, Turkey 2001 Review, International Energy Agency; 2001.
[12] Altaş M, Özkan HF, Çelebi E. 2002 Energy Statistics. Istanbul: Turkish National Committee of World Energy Council; 2003 [in Turkish].
[13] Turkish Statistical Institute (TURKSTAT). http://www.tuik.gov.tr.
[14] Press Release; March 7, 2005. http://www.wwindea.org.
[15] Global Wind energy Market Report; February 2003. http://www.awea.org.
[16] Global Wind energy Market Report; May 2001. http://www.awea.org.
[17] van Wijk AJM, Coelingh JP. Wind Power Potential in the OECD Countries. Netherlands: Utrecht University; 1993.
[18] General Directorate of Electrical Power Resources (EIE), Turkey's wind map. http://www.eie.gov.tr.
[19] State Planning Organisation (DPT), 8th Development Plan, Electrical energy special specialisation commission report, Ankara [in Turkish]. http://ekutup.dpt.gov.tr/enerji/oik585.pdf.
[20] Turkish National Committee of World Energy Council (DEKTMK). 2002 Turkey's energy report [in Turkish].
[21] Aras H. Wind energy status and its assessment in Turkey. Renew Energ 2003;28:2213–20.
[22] Minimum price system with the quota model—which system is more efficient?; June 2005. http://www.wind-energie.de.
[23] Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy. Law No. 5346. Official Paper. Enactment Date: May 18, 2005. http://rega.basbakanlik.gov.tr/Eskiler/2005/05/20050518-1.htm.
[24] World Wind Energy Association. Press Release. Turkish Parliament adopts the renewable law. May 2005. http://www.wwindea.org.